Effect of Fault Dip and Slip Rake Angles on Near-Source Ground Motions: Why Chi-Chi Was a Relatively Mild M 7.6 Earthquake

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Summary

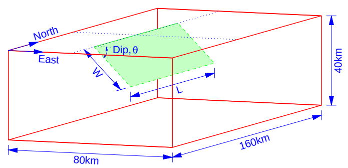
We study how the fault dip and slip rake angles affect near-source ground motions as the faulting mechanism transitions from strike-slip motion on a vertical fault to thrust motion on a shallow dipping fault.

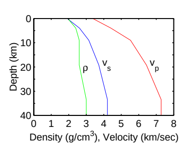
Methodology

- 3-D dynamic elasticity
- Unstructured, tetrahedral finite-element mesh
- Prescribed rupture speed and slip time histories

Scenarios

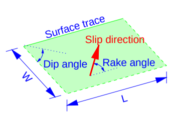
- Moment magnitude: 7.4
- Uniform peak slip rate: 2.0m/sec
- Rupture speed: 85% shear wave speed parallel to slip
  68% shear wave speed perp. to slip

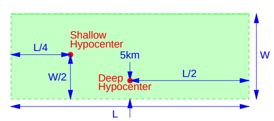




Fault Geometries

Fault Dip	Slip Rake	Fault Length	Fault Width
90°	0°	120km	20km
75°	22.5°	110km	22km
60°	45°	100km	24km
45°	67.5°	90km	27km
30°	90°	80km	30km





Scenario with 30° dipping fault and shallow hypocenter closely resembles the 1999 Chi-Chi, Taiwan, earthquake.

Shallow Hypocenter

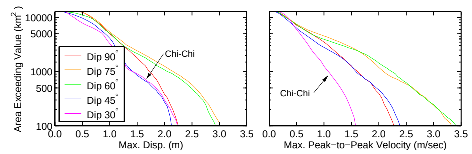
Maximum Values on Ground Surface

Fault Dip	Max. Horiz. Disp.	Max. P-to-P Horiz. Vel.
90°	2.6m	2.6m/sec
75°	3.3m	3.7m/sec
60°	3.2m	4.2m/sec
45°	2.2m	2.7m/sec
30°	3.1m	1.7m/sec

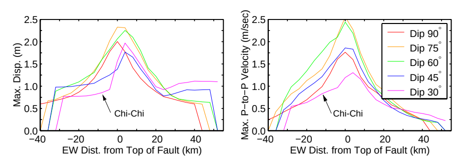
Chi-Chi →

Deeper Hypocenter →

Ground Area Where Motion Exceeds Given Level



Mean Peak Values Versus Distance

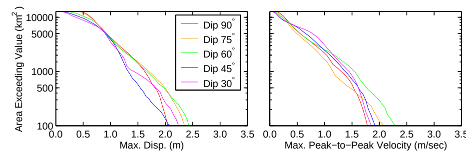


Deep Hypocenter

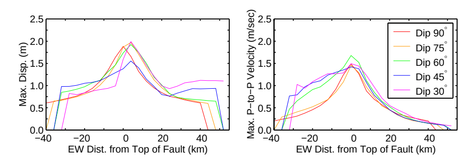
Maximum Values on Ground Surface

Fault Dip	Max. Horiz. Disp.	Max. P-to-P Horiz. Vel.
90°	2.6m	2.0m/sec
75°	3.1m	2.8m/sec
60°	2.8m	2.8m/sec
45°	2.3m	2.4m/sec
30°	3.1m	2.2m/sec

Ground Area Where Value Exceeds Given Level

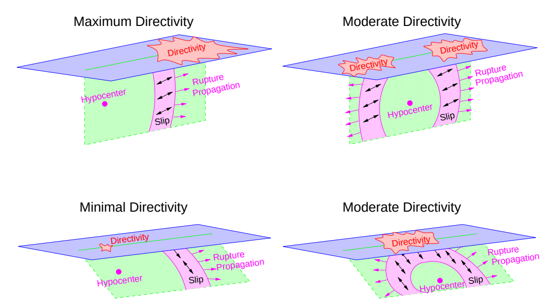


Mean Peak Values Versus Distance



Conclusions

- **The fault geometry and shallow hypocenter of the Chi-Chi earthquake minimized the amplitude of the near-source velocity pulses.**
- We should expect larger amplitude velocity pulses for other styles of faulting or a deeper hypocenter.
- The amount of rupture in the direction parallel to slip controls the near-source effects.
- For strike-slip motion near-source effects are most severe for unilateral rupture.
- For thrust motion near-source effects are most severe for up-dip rupture.



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Technical report available at http://pasadena.wr.usgs.gov/office/baagaard/research